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DIVISION OF ENGINEERING SERVICES
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METHOD OF TEST FOR FLEXURAL STRENGTH OF CONCRETE

A. SCOPE

This test method describes the procedure used for determining the flexural strength of concrete by two different methods:

Method 1: a simple beam with center-point loading.

Method 2: a simple beam with third point loading.

Both tests are intended to be used to determine modulus of rupture and are considered to give equivalent answers.

B. REFERENCES

California Test 539 - Method of Test for Sampling Fresh Concrete
ASTM E4 - Standard Practices for Force Verification of Testing Machines

C. APPARATUS

1. Testing machine:

The testing machine shall conform to the requirements of Sections 16, 17, and 18 of ASTM E4.

Hand operated testing machines having pumps that do not provide a continuous loading in one stroke shall not be permitted. Motorized pumps or hand-operated positive displacement pumps having sufficient volume in one continuous stroke to complete a test without requiring replenishment are permitted and shall be capable of applying loads at a uniform rate without shock or interruption. The loading device shall employ bearing blocks, which will ensure that forces applied to the beam will be perpendicular to the face of the specimen and applied without eccentricity.

2. Beam molds:

- a. Molds shall be made of steel, cast iron, or other nonabsorbent material and be nonreactive with concrete containing portland or other hydraulic cements.
- b. Molds shall maintain their dimensions and shape under conditions of severe use.
- c. Molds shall be mortar tight during use. A suitable sealant, such as sealing caulk, heavy grease, modeling clay, or microcrystalline wax, shall be used where necessary to prevent leakage through the joints.

- d. Positive means shall be provided to hold base plates firmly to the molds. Molds shall be lightly coated with mineral oil or another suitable nonreactive release material before use.
- e. The molds shall be 6 in. × 6 in. in cross section and a minimum of 32 in. in length for Method 1, and a minimum of 20 in. in length for Method 2.
- f. The surface of the molds shall be smooth and free from blemishes.
- g. The sides, bottom, and ends shall be at right angles to each other and shall be straight, true, and free of warping.
- h. Maximum variation from the nominal cross section shall not exceed $\frac{1}{8}$ in.

D. TERMINOLOGY

- 1. Tamping rod: a round, straight steel rod with a diameter of $\frac{5}{8}$ in. $\pm \frac{1}{16}$ in. and length of at least 4 in. greater than the depth of the measure in which rodding is to be performed, but not more than 24 in. One or both ends of the tamping rod must be rounded to a hemispherical tip of the same diameter as the rod.
- 2. Small tools: Items such as shovels, scoops, pails, trowels, wooden floats, rubber hammers, and sponges.

E. CALIBRATION OF APPARATUS

- 1. Method 1 – Beam breaking machine.

The beam breaking machine applies a load at the midpoint of a 30 in. span by means of a gage-equipped hydraulic jack. The gage is subject to error and must be calibrated before use on each project. The calibration can be made by using a calibrated compression testing machine in the district laboratory.

- a. Place the jack in the compression testing machine in the same (inverted) position in which it is used in the beam testing machine.
- b. Apply the load by turning the crank of the jack; do not apply load by operating the compression testing machine.
- c. Record the corresponding reading on the compression testing machine indicator as the needle of the gage reaches each 1,000 lb increment.
- d. Attach a table to the jack showing the correction to be applied to each 1,000 lb increment of gage reading and include date of calibration on the table. Make up this table so that a plus correction will indicate the amount to be added to the observed gage reading and a minus correction will indicate the amount to be subtracted.
- e. Send jacks in to the Transportation Laboratory, Structural Materials Testing Branch for adjustment if they are found to be in error by more than 500 lb at any point.

2. Method 2 – Beam breaking machine.

Calibrate the beam breaking machine in accordance with the manufacturer's recommended procedure or ASTM E4 at least once every 12 months.

F. PREPARATION OF TEST SPECIMENS

1. Sampling fresh concrete:
 - a. Obtain a sample of concrete from the mass during the placing operation (see California Test 539).
 - b. Transport samples in watertight containers to the place where the test specimens are to be molded.
 - c. If any of the aggregate used is retained on the 1½ in. sieve, screen the concrete sample through a 1½ in. sieve and discard the oversize aggregate.
 - d. Always remix the sample with a shovel on a nonabsorbent surface to assure that there is no segregation of the coarse aggregate or mortar.
2. Molding test specimens:
 - a. Before each use, apply a release agent such as a light coat of fresh oil to all inside surfaces of the mold.
 - b. Place concrete in the molds in two approximately equal layers. Rod each layer 60 times for 20 in. beams or one stroke for each 2 sq. in. of surface. Do not stroke the bottom of the mold with the rod. For the second layer, rod ½ in. into the first layer. Tap the sides of the mold lightly with a rubber mallet to close the voids. Spade the concrete along the sides and ends of the beam molds with a trowel or other suitable tool to remove air voids.
 - c. Strike off surplus concrete and finish the surface with a wood float.
 - d. Finish with the minimum manipulation necessary to provide a flat, even surface that is level with the rim or edge of the mold.
3. Curing test specimens:
 - a. Place earth or sand around the sides and ends of the molds to prevent excessive loss of the heat generated by cement hydration in the concrete.
 - b. Apply the same curing medium to the top surface of the test beam as is applied to the pavement. If application of the specified curing medium is delayed, cover the beam immediately with a double thickness of burlap or other fabric, which shall be kept thoroughly damp until the membrane is applied.
 - c. At the end of approximately 24 hr, remove the mold and transport the beam resting on its base plate to the curing location.

- d. Carefully remove the beam from the base plate and bury the beam in damp earth or sand with at least 4 in. of cover.
- e. Bury beams Saturday that are cast on Friday.
- f. Keep the earth or sand surrounding the test beams damp at all times, and cover with a tarpaulin or sisal kraft paper to prevent the cooling effect of excessive evaporation.
- g. Place test specimens in a saturated-lime water bath $24 \text{ hr} \pm 6 \text{ hr}$ before testing. The saturated-lime water bath shall be $73.4^{\circ}\text{F} \pm 9^{\circ}\text{F}$. Store the specimens in the saturated-lime water bath until the time of testing.

NOTE: Keep the beams thoroughly damp throughout the curing period. Even a few minutes exposure of beams to drying can seriously affect the test strength.

G. METHOD 1 – BEAM BREAKING

- 1. Procedure:
 - a. Position the testing machine on a firm foundation well removed from the influence of jars and vibration caused by passing traffic.
 - b. Brush the beam clean. Turn the beam on its side, with respect to its position as molded, and place it in the breaking machine.
 - c. Set the bearing plates square with the beam and adjust for distance by means of the guide plates furnished with the machine.
 - d. Place a strip of leather or similar material under the upper bearing plate to assist in distributing the load.
 - e. Bring the plunger of the jack into contact with the ball on the bearing bar by turning the screw in the end of the plunger.
 - f. After contact is made and when only firm finger pressure has been applied, adjust the needle on the dial gage to "0."
 - g. Apply about 400 lb of force with the lever pump to seat the beam firmly in its supports and then remove the guide plates. Always remove the guide plates before proceeding further with the test.
 - h. Retract the screw pump to its outer limit by turning the crank in a counterclockwise direction. While doing this, avoid drawing air into the cylinder of the screw pump; maintain about 400 lb of force on the gage by manipulating the lever pump.
 - i. Turn the handle of the screw pump in a clockwise direction at a rate such that the gage reading increases at a rate of 600 to 800 lb/min.
 - j. Continue turning the screw pump handle until the beam breaks and record this maximum load in pounds as value of P^1 .

2. Calculations:

- a. Apply the correction indicated on the calibration table that is attached to the jack (see Section E.1.d.) to P^1 and record this corrected load in pounds as the value of " P ."
- b. Measure to the nearest $1/16$ in. the width of the beam at the tension side of the plane of fracture and record this width as the value of " b ."
- c. Measure to the nearest $1/16$ in. the depth of the beam at three points across the plane of fracture.
- d. Take the average of these three measurements as the depth and record as the value of " d ."
- e. Calculate the modulus of rupture from the following formula:

$$R = 1.5 (Pl/bd^2)$$

where: R = modulus of rupture, psi

P = corrected load on beam, lb

l = span between centers of lower supports, in.

b = average width of beam, in.

d = average depth of beam, in.

NOTE: Consider the results of any test unreliable if fracture occurs in a plane removed more than 3 in. from the plane of load application, if there is evidence of partial drying across the plane of fracture, or if pieces of wood or an unusual collection of soft aggregate appear in the plane of fracture. (It is normal for a few pieces of coarse aggregate near the tension face to be fractured.)

Do not allow the plunger of the jack to extend more than 3 in. beyond the body of the jack. When it is necessary to shorten the plunger travel, open the release valve and force the plunger back with a lever.

If air enters the pumping system in appreciable quantity, it will be impossible to build up pressure on the jack to its full gage capacity. To remove air, open the release valve and force the plunger of the jack to its closed position, then bring the screw pump to its closed position and close the release valve. Next, insert an unbroken beam or a timber in the frame of the machine and operate the lever pump until approximately 500 lb of force is registered on the gage. Then, retract the screw pump to its outer limit while maintaining gage force with the lever pump. It may be necessary to repeat the above steps to remove all of the air from the pumping system. If more convenient, detach the jack from the testing frame and place in a testing press for performance of the above steps.

Keep the release valve closed at all times except when necessary to make adjustments. This is a precautionary measure against entrance of air into the pumping system. The beam breaking machine is so designed that it is not necessary to remove any of the

permanent connections either when operating or transporting. However, it is advised that the jack be removed for storing or shipping.

The moment due to the dead weight of the beam is not included in the above formula because the value of the moment is insignificant.

H. METHOD 2 – BEAM BREAKING

1. Procedure:

- a. Position the testing machine on a firm foundation well removed from the influence of jars and vibration caused by passing traffic.
- b. Turn the test specimens on its side with respect to its position as molded and center it on the bearing blocks.
- c. Center the loading system in relation to the applied force.
- d. Bring the load applying blocks in contact with the surface of the specimen at the third points between the supports. Check that “full contact” is obtained between the specimen and the loading blocks and supports. When there is not full contact, grind or cap the contact surfaces of the specimen, or shim with leather strips (see notes on Method 2).
- e. Apply the load continuously at a rate that constantly increases the extreme fiber stress from 125 to 175 psi/min until rupture occurs. When the approximate failure load is known, the load may be rapidly applied to approximately 50 % of the breaking load.

2. Calculations:

- a. Measure to the nearest $1/16$ in. the width of the beam at the tension side of the plane of fracture and record this width as the value of “*b*.”
- b. Measure to the nearest $1/16$ in. the depth of the beam at three points across the plane of fracture.
- c. Take the average of these three measurements as the depth and record as the value of “*d*.”
- d. When the fracture initiates in the tension surface within the middle third of the span length, calculate the modulus of rupture as follows:

$$R = 1.05 Pl/bd^2$$

where: R = modulus of rupture, psi

P = maximum applied load indicated by the testing machine, lb

l = span length, in.

b = width of specimen, in.

d = average depth of specimen, in.

- e. When fracture occurs in the tension surface outside of the middle third of the span length by not more than 5 % of the span length, calculate the modulus of rupture as follows:

$$R = 3.15 Pa/bd^2$$

where: a = average distance from line of fracture to the nearest support measured on the tension surface of the beam, in.

- f. If fracture occurs in the tension surface outside of the middle third of the span length by more than 5 % of the span length, discard the results of the test.

NOTE: "Full contact" is obtained when no more than $3/4$ in. of load bearing block length has a gap in excess of 0.004 in.

It is recommended that grinding surfaces of the specimens be minimized as it may change the physical characteristics of the specimens and thereby affect the test results.

Use leather shims only when the specimen surfaces in contact with the blocks or supports depart from a plane by no more than 0.015 in. Leather shims shall have a nominal thickness of $1/4$ in., shall be $3/4$ to 2 in. wide, and shall extend across the full width of the specimens.

If fracture occurs at a capped section, include the cap thickness in the measurement.

I. REPORT

The report shall include the following:

1. Identification number.
2. Measured width to the nearest $1/16$ in.
3. Measured depth to the nearest $1/16$ in.
4. Span length in in.
5. Maximum applied load in lb.
6. Test method used (e.g., CT 523 Method 2).
7. Modulus of rupture calculated to the nearest 10 psi.
8. Curing history and apparent moisture condition of the specimens at the time of test.
9. If specimens were capped, ground, or if leather shims were used.

10. Defects in specimens.
11. Age of specimens.

J. PRECISION AND BIAS

Difference in the individual test results of beams aged 28 days (tested by the same operator) must not exceed 12 % when tested by Method 1 or 16 % when tested by Method 2. When tested at two different laboratories, the results must not exceed 15 % when tested by Method 1 or 19 % when tested by Method 2.

K. PRECAUTIONS

Portland cement, when mixed with water, makes an alkaline solution. Contact with the skin can cause drying and cracking or dermatitis. Take care to prevent skin contact by wearing impervious gloves. If skin contact occurs, wash promptly with soap and water.

Fabricating and testing concrete specimens often involves lifting and stooping. Use proper lifting practices to prevent injury.

L. HEALTH AND SAFETY

It is the responsibility of the user of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Prior to handling, testing, or disposing of any materials, testers must be knowledgeable about safe laboratory practices, hazards, and exposure, chemical procurement and storage, and personal protective apparel and equipment.

Caltrans Laboratory Safety Manual is available at:

http://www.dot.ca.gov/hq/esc/ctms/pdf/lab_safety_manual.pdf

Users of this method do so at their own risk.

End of Text
(California Test 523 contains 8 pages)